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HOW TO DX EARTH RADIO FROM OUTER SPACE

A PRACTICAL ANALYSIS OF HOW RADIO AND TV DX'ERS CAN, ONE DAY, PURSUE THEIR HOBBY ON THE MOON OR OTHER COLONY IN SPACE

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Some day in the not-too-distant future, permanent human colonies will be established in space and on the surfaces of other planetary bodies. The colonists inhabiting them will, naturally, be interested in what's happening on earth. An ideal way to find out will be to tune in domestic broadcasts from earth.

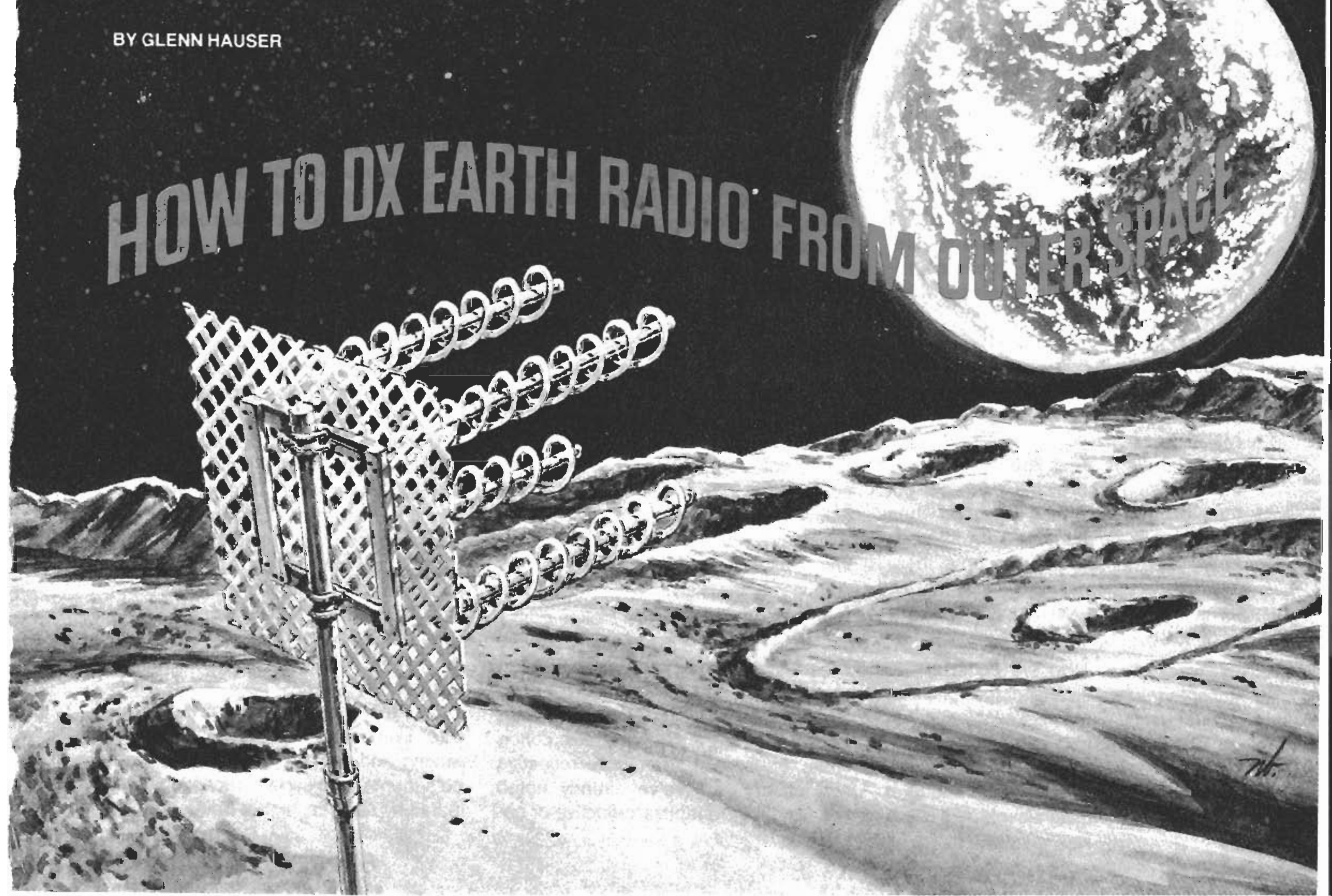
There will doubtlessly be direct communications links using giant dish antennas, but these will carry only selected programs. Here is a futuristic—but practical—analysis of how DX'ers might pick up earth broadcasts not deliberately beamed into space.

Practical Considerations. Besides the obvious limitations of receiver and antenna gain, several factors will determine which earth stations can be received. Let's take as the most likely example a DX'er on the moon. Radiated signal power, frequency, channel usage, geography, and ionospheric conditions are all important.

All signals, of whatever frequency, become progressively weaker with distance according to the inverse square law. You might think that, at a distance as great as 400,000 kilometers, hardly any signal would be left. But that isn't so! A 100,000-watt station (the common effective radiated power of U.S. FM broadcasters) would still put in a 4.5-μV/meter signal as far away as the moon—and that's plenty for any good FM tuner on the market today.

We obtain the 4.5-μV/m field strength by the standard inverse-square formula for the ideal line-of-sight case. We approach line-of-sight in the earth-moon case more closely than over single-planet paths where the curvature of the body and the distance of the radio horizon are all-important. However, atmospheric scattering before the signal enters free space will diminish the 4.5μV/m figure by an unknown, but not unmanageable, amount. In fact, the moon is constantly bombarded by a cacophony of earth signals. The problem will not be to pull them in, but to discriminate between them!

Antennas. On the moon there is lots of room to put up the most efficient receiving antennas possible. In fact, huge high-gain arrays could be erected much more easily in the moon's one-sixth gravity. Because the apparent position



of the earth in the lunar sky varies only slightly, antennas could be permanently aimed toward earth, never having to track the planet. However, extremely directional antennas capable of picking out signals 2° apart would have to be slightly movable. Two degrees is the apparent diameter of the earth as seen from the moon—four times the size of the moon in the terran sky. Apart from this, lunar libration causes the position of the earth to oscillate very slightly in the sky.

The ideal receiving antenna for the mediumwave band, the Beverage, would be easier to build on the moon because it would weigh less and require fewer support poles. But because of the moon's greater curvature, it would be more difficult to keep it going in an absolutely straight line over several kilometers. As it receives off its end, rather than broadside, it would have to be built near the moon's limb where the earth hangs near the horizon. Alternatively, it could be run up a mountain slope so it would still point toward earth.

Earthlings seldom consider the fact that almost all transmissions, whether vertically or horizontally polarized, are broadcast into the horizontal plane. Very little of the signal goes straight up, or at angles much above the horizon. There has never been a marketable audience in those directions! True, there are occasional manned satellites, and airplanes; but they pass quickly out of range, and even most satellites are no farther over a station than their fringe-area listeners on earth.

Although the earth looks like a disc from the moon, we know it's a sphere. As seen from the moon, the earth rotates once about every 24 hours—which means there's a regular daily cycle of stations to be heard one after another, for perhaps an hour at a time, depending on the effective radiated power and the broadness of each signal beam vertically above its horizon.

The stations near the approaching and receding limb of the earth put out the most power towards the moon when the moon is near the horizon as seen from the earth. (Unless, of course, there are nulls in the stations' directional patterns where the moon happens to be.)

Frequencies. Now we come to the advantages and disadvantages of different frequency bands. Let's look at mediumwave first. We've all heard speculation about the sphere of broadcasts expanding from the earth at the speed of light, with the leading wavefront already some 55 light years distant. This sphere is announcing to the universe that creatures in the solar system have reached a technological level capable of broadcasting. Any intelligent beings of the same or greater technological level within this sphere have probably begun to acquaint themselves with human civilization as portrayed in our broadcasts. But the earliest broadcasts were on mediumwave. It turns out this is the worst band of all for reaching the cosmos—for the same reasons that it is the best one for reliable domestic broadcasting beyond the horizon! When it is night on the earth, MW signals are for the most part returned back to earth by the upper regions of the ionosphere. Relatively little of their energy escapes into space. When it is day on the earth, most of the signals are absorbed by the D layer, again preventing escape into space. For these reasons, there may be less pre-1940 AM radio from earth floating around in space than we might like. Longwave broadcasts (currently from Eurasia and Africa only) have about the same characteristics as mediumwave, except for much greater groundwave range. The greater number of superpower transmitters on LW might improve the chances for escape into space. But all is not lost, thanks to shortwave and vhf!

Back in the 1920's, shortwave frequencies were thought to be useless so all early broadcasts were on medium or longwave. Yet unintentional harmonics from mediumwave stations did get out on shortwave. In fact, it was receiving these harmonics which piqued interest in exploring the higher frequencies.

Because AM broadcasts signals are the least ideal to penetrate space, it may well be that the now-almost-forgotten shortwave simulcasts of AM stations in the 1920's and 1930's—KDKA, WLW, WIOD, and the New York flagship stations—are the signals carrying news of humanity into the cosmos. The early FM simulcasts in the 40-MHz band serve even better. This assumes that the mediumwave harmonics, shortwave and FM relays were above the MUF (maximum usable frequency) much of the time, as seems likely.

Just as the ionosphere makes possible long-distance communication between different points on earth, it is an obstacle to communication from earth to other planets. We can divide the ionosphere into three different basic conditions: transparent, refractive/reflective and absorptive. We've already noted that it's either refractive/reflective or absorptive on mediumwave. But it behaves much differently at higher frequencies. At a constantly changing shortwave frequency we find the MUF. Above this frequency, most radio energy escapes into space. Fortunately for our DX'ers in space, the ionosphere at SW is a much less reliable refracting medium than it is at MW. It is also much less subject to absorption.

On earth, the ionosphere causes such wide variations in propagation efficiency, that even the lowest power SW transmitter has an occasional chance of reaching the other side of the world. But how well are shortwave broadcasts likely to get through to the moon? When we're talking about a distance of some 400,000 km, a few thousand kilometers, one way or another is insignificant. Here is where raw power could really pay off. On earth, a great fraction of a 500-kW shortwave transmitter's output goes to waste; that's why a 5-kW station on the next frequency can be heard just as well, depending on conditions. But the 500-kW SW transmitter is going to have a much better chance of being heard on Luna than the 5-kW outlet, because the inverse square law will provide more usable signal.

SW broadcasters stick to a fixed schedule, from day to day, initiating major changes four times a year. This means that on a given day they may be putting out hundreds of kilowatts on frequencies which happen to be above the maximum usable frequency under existing conditions. So most of this radiation goes right out into space, where lunar colonists can make good use of it!

Because SW is the band which normally propagates from one side of the earth to the other, it follows that not all SW stations received on the moon would be on the visible side of the earth. The first hop or two could be bent around the "terran limb," just so the last one 'hops out' into space.

Time of day on earth has a great bearing both on terran SW frequency usage and on propagation. That is, they depend on whether the path is in darkness, in light or both. We should also consider this from our lunar vantage point. Our lunar days and nights are each 14 earth days long. As we observe the earth, we can see its phases changing at exactly the same rate that the lunar phases change as viewed from earth. This means that the proportion of the terran disc in darkness changes gradually, waxing and waning. Thus, there would be a month-long cycle of reception dominated by daytime, higher-frequency SW transmissions from the region of the illuminated limb, and lower frequencies from the region of the limb in darkness. However, since the earth is rotating through day and night each 24 hours, all countries would be 'in view' each day.

The moon has no significant ionosphere, so any changes in reception will be due to variations at the earth end of the path—except during solar disturbances, when both earth and moon receive the same effects. But the sun can still cause problems when it's quiet. It normally radiates a great deal of noise at certain frequencies. Using directional antennas trained on earth, solar noise should only be a problem when the earth is near its 'new' phase, with the terran disc a thin crescent or totally dark. That's when the sun is in almost the same direction. During total solar eclipses on the moon (by the earth, of course), both earth and sun are in exactly the same direction. We'd have the same problem on earth receiving lunar stations, if there were any, when the moon is new or eclipsing the sun.

As soon as there is a significant permanent population on the moon or elsewhere, there will be local broadcasting stations—hot targets for earthbound DX listeners, just like the remote American Forces Antarctic Network is today. The only transmitters which have operated from the lunar surface to date have been in the tens-of-watts range—just enough for communications efficiency with an orbiter, or a giant dish receiving antenna back on earth.

Next we come to the vhf and uhf broadcasting bands, which are used for television and FM radio. Under normal circumstances, these signals go off into space after they pass the 'radio horizon' of their coverage area. The ionosphere is normally transparent at these frequencies, and powers as high as 5000 kW ERP are used! Receiving such signals on the moon should be easiest of all. Furthermore, the higher the frequency, the smaller the antenna, which means a high-gain antenna can be constructed more economically at uhf than at hf.

There are circumstances when some vhf signals do get trapped in the ionosphere and sent back to earth. Sporadic E is the most common example. These swiftly moving patches of ionization, increasingly restricted geographically with higher frequencies, are the prime means of vhf DX on Earth. But from the spatial point of view, they are potential interruptors of reception. True, they could on rare occasions bring in a TV or FM signal from beyond the limb of the earth, but so what? The same station could be received direct a few hours earlier or later, as the earth's rotation brings it into position.

Another obstacle to both vhf and uhf signals penetrating into space is the occasional inversion layer causing widespread 'tropo' DX on earth. However, it's doubtful that *all* of a station's signal is trapped on earth by tropo.

"Selectivity." On vhf and uhf, the major problem is likely to be *too many* stations coming in at once—with roughly equal signal strength—on the same channels. This will be alleviated by the 'limb effect', when stations on the limb of earth at any given moment dominate since most of their power is radiated into the plane in which the moon lies. But because high-power FM and TV broadcasting is concentrated in relatively small areas of the globe (North America and Europe), there will be no way to separate stations by antenna directivity. All is not lost, however.

The FM "capture effect" would save the day when there is a significant difference in signal strength. The one strongest signal would be heard, and all the others rejected. However, this has its limits, as we can observe here on earth. There have been sporadic E openings blanketing a major portion of the United States, bringing in dozens of FM stations at the same time on each channel, and at such similar strengths that only occasionally would one rise sufficiently above the hash to be identified. It couldn't be much better at a reception point where all these stations would put through signals continuously. And the capture effect applies only to FM transmission, used for FM radio and TV audio only. TV video would be a huge conglomeration of beat bars, completely unviewable, unless we pick our targets very carefully.

Though all these stations would be reaching the moon, there still would be a great deal of DX challenge in picking individual stations out of the melange. There would be several ways to do it. The best would be to tune at a time when only one station happens to be on the air on its channel in a wide geographical area—such as the still small number of all-night TV stations in North America. But this is hardly prime-time television. Those intelligent beings somewhere in the 5-to-20 light year range from earth are most likely viewing old movies on all-night TV stations, no doubt getting an even less reliable impression of life on earth than they would get from prime-time or 'daytime' viewing, when every TV station is on the air simultaneously!

Another way to get intelligible video from earth is to pick a channel which happens to be sparsely occupied. In practice, this means the high end of uhf or the low end of vhf. In earthly terms, any station relegated to the high end of the uhf band feels it's got a raw deal, and does everything possible to move to a lower uhf channel, or preferably vhf. For example, a Washington, D.C. TV station on channel 53 recently went on channel 14 as well, where fewer people would be likely to miss it.

But for interplanetary television, those stations on isolated higher channels suddenly are at a great advantage! There's only one channel 68 station in North America (other than low-powered translators), an independent in Los Angeles running a million watts. They'll be a big draw on the moon. Down one, at channel 67, viewers can get PBS through the Baltimore station running only 650,000 watts ERP. All the lower channels have more than one U.S. station, though there are certainly times when only one is on the air, or on the visible side of the earth, or both.

A similar situation exists in Europe. British ITA from Dover would come through on European channel 66 without interference, if its paltry 100,000 watts video ERP could achieve an adequate signal-to-noise ratio at lunar distance. France's program 2 from Aurillac is on another exclusive channel, 65. This one has 500,000 watts. But all the lower uhf channels are occupied by several powerful transmitters in each country. They usually carry the same program per country, but that wouldn't keep them from mutually interfering.

Brazil is another country with some uhf broadcasting, and it is sufficiently far from North America and Europe to be the only visible uhf area at certain times. Our latest reference shows single station occupancy of channels 17, 19 and 22, though each uses only a 50-kW transmitter. Of course, these happenstance "unique" channels may be long gone by the time lunar colonists have settled and have some spare time for TV DX'ing!

Japan is the only other major uhf TV area in the world so far. Unfortunately, powers are relatively low, and the only exclusive channels are occupied by low-power stations. So getting viewable Japanese TV on the moon would be doubtful, depending on whether it was the only country on the air at a given hour, and if there was only one station on the air on a given channel.

Besides the exclusive channels on the high end of the uhf TV band, there are others at the bottom of the vhf range. For example, on 45.0 MHz video/41.5 MHz audio, there is one high-power TV station in London, and a number of lower-powered repeaters. Although these frequencies are used for two-way communication in other parts of the world, nowhere else on earth are there TV stations on these frequencies. Also, it's unlikely that any of the interference sources would have a power output approaching 200,000 watts. Unfortunately, this BBC channel is considered antiquated and due to be phased out in favor of uhf.

Another maverick TV station that might be seen on the moon better than in most of Australia is the only station in the world on 138.25/143.75 MHz, Australian channel 5-A—ABWN, with 100/20 kW of output, at Wollongong, N.S.W.—if *it* still exists. The forces of standardization are cruel! Actually, the 2500-MHz Instructional Television Fixed Service band (as it is called in the U.S.) is at a more favorable frequency range for interplanetary DX than even uhf TV. Unfortunately, powers are low and directionality is extreme, so like TV microwave links on even higher bands, it's doubtful that they could be seen at lunar distances.

Lest you think this is all too far-fetched, ham operators have been working each other by EME (Earth-Moon-Earth) or "moonbounce," for many years—with the limitations on power inherent in amateur radio. If hams can make contact by reflecting off the moon on the 432-MHz band (near channel 14) as well as 1296-MHz band (above channel 83)—frequencies at which a large fraction of the transmitted power is absorbed and scattered—it seems a certainty that broadcasting stations with much higher power could be received on the moon. In fact, there's a marginal chance that intercontinental uhf TV DX (at least the audio channel) would be possible via moonbounce. The best way to find out would be to dedicate a huge radio telescope to moonbounce TV DX during the brief periods when the moon is in a favorable position.

Certain channels in the FM educational band (88–92 MHz) contain only one powerful station in North America along with many lower-powered ones. This means that the one strong station would be essentially free of interference on the moon due to the capture effect. For example at 88.1 MHz (which is avoided by FM stations in most areas because it is close to TV channel 6) there is a single 98-kW station: WMPR, Sumter, SC. The next strongest at that frequency is in Lubbock, TX, with only 18.5 kW. At 89.1 MHz, there is the 100-kW WVWR in Roanoke, VA, which is followed by an 11-kW station in Schenectady, NY.

It's a safe bet that these stations haven't realized what a potential competitive advantage they have in space! Even greater advantages are held by some Canadian stations operating what the U. S. calls "Class A" channels. U. S. stations are uniformly limited to 3kW, while Canadians such as CKY-FM, 92.1, in Winnipeg runs 360 kW; CKSO-FM, 92.7, Sudbury, has 100 kW; CBW-FM, 98.3, Winnipeg, 354 kW; CBZF, 102.3, Fredericton, 100 kW. A number of other Class-A channels harbor more than one high-power Canadian.

It's a shame that no lunar expedition to date has included a multi-band receiver to check for Earth DX. The Manned Spacecraft Center informed me they were aware of no such experiment, although ESP definitely was tried!

Relays and Receivers. Once there are permanent habitations on the moon and travel there becomes more routine, it will be hard to resist using it as a relay base for international broadcasting. There may be international treaties preventing it, but this is not a real obstacle. A station doesn't need to reveal where it is being relayed from. Radio Moscow never admits that it is relayed from two sites in Bulgaria, for example, so why not set up a lunar relay, using FM on the 25-MHz band? Of course, a lunar relay site would be useful only 12 hours a day when the moon is in view—and the 12 hours would shift over the entire 24-hour day during a month's time.

The BBC keeps putting up new relay sites, despite budget cuts, so the moon is a logical projection of this trend. Again, should there be any political reasons for broadcasting from the moon without admitting it, the BBC also has a precedent—its regular use of relays by the VOA, never specified as such in its published schedules.

The far side of the moon is the ideal place to monitor for broadcasts from other civilizations, for only on the far side is the cacophony from earth shielded. However, even on the near side, it may be possible to receive messages from other worlds. This is an improvement from trying to do it from earth. But there's another reason. We take our basic unit of time, the second, completely for granted, though it is arbitrary. There is really no chance at all that any other civilization would have precisely the same time unit, unless they derived it after hearing our broadcasts. Thus, any physical quantities involving time, such as radio frequency, would not be in increments referenced to our seconds. This means that even if they used the decimal system (which is another unwarranted assumption), and used the same absolute frequency band for FM broadcasting (88–100 MHz), their channel spacing would inevitably be different from ours. Two hundred kHz is 200,000 cycles per second, and their cycles would be measured against something other than a second! Therefore, most or all of their transmissions would be on what DX listeners call "split" frequencies—allowing them to be heard between earth-based frequencies.

Cities in space would encounter exactly the same reception conditions from earth as those on the moon. However, the logistics of antenna building and aiming would be quite different in a rotating, free-fall environment.

Earth reception on Mars or the Jovian satellites would be similar, but presents greater problems—greater distances, Martian atmospheric effects, the earth as a point source (allowing no practical discrimination between approaching- and receding-limb stations), and the fact that earth would never stray too far in the sky from the sun (a considerable noise source against the intrinsically weakened earth signals). R-f from the planet Jupiter itself would be capable of blotting out broadcast reception from earth on some frequencies. In fact, we can hear that noise right here on earth if we know where to tune and how to recognize it.

Monitoring earth broadcasts on Mars would underline the tremendous distance involved. One would presumably have an atomic clock running on earth time (UTC), but even so there would be a signal propagation delay ranging from 3 to 22 minutes. The delay would vary so widely because the distance between the two planets varies more, in fact, than the distance from earth to any other planet. If earth-based TV programs were observed to start a given number of minutes late, the distance to earth at that particular instant could be easily calculated.

People with many different avocations have walked on the moon already. It's about time a skilled DX listener/viewer had a chance. NASA and other agencies, please note—I volunteer! ◇