Microwave Engineering Project (MEP) Update
The Problem is Pointing

Most microwave stations use dish antennas. Dish antennas at the frequencies of operation of interest to MEP, which range from 3.4GHz to 5.6GHz, have a very narrow beamwidth. For example, a half-meter dish at 3.4GHz has a half-power beamwidth of 12 degrees. A half-meter dish at 5.6GHz has a half-power beamwidth of 7.5 degrees. These narrow beamwidths mean that unless you are pointing your dish in the right direction and at the correct elevation, you will not hear the other station. Proper pointing is crucial.

Traditional methods of accurately pointing one microwave station at another include setting up a fixed set of antennas, using calibrated setting circles on tripods and knowing the precise bearing to the other stations, guessing and searching by moving the dish around, and by using known locations of beacons to contact stations prepositioned near or at the beacon. Many microwave-band contacts are made during microwave band contest with prior planning and advance coordination.

Station discovery is the process of learning about other stations in range of the searching station in order to establish communications. For MEP, station discovery is intended to be a designed-in distributed method that allows stations to discover their current network environment as automatically as possible. Ideally, stations should also be able to advertise their current and potential configurations and services to other stations.

The methods of station discovery under discussion are

- increasing the beamwidth
- using APRS query/response and filtering the replies
- using omnidirectional in-band beacons and in-band signaling

The discovery function that MEP is working on is exciting because it reveals stations that the operator may not know about, allows for opportunistic contacts, and allows the operator to watch, filter, and monitor activity on the microwave bands without having to personally monitor the station.

For a parabolic antenna, the process of increasing the beamwidth for a fixed size dish usually comes at the expense of gain. This naturally leads to the question of whether or not the increased-beamwidth dish's "discovery range" would be too small to be useful. The working range is defined by signal strength required to close the full link at its high bit rate. The discovery range, the range over which a searching station can discover other stations, only needs signal detection and perhaps identification. MEP assumes that there is enough difference between the discovery range and the working range to trade bandwidth for beamwidth in order to enable faster and easier signal searching.

In comparison, weak-signal DX microwave communications are achieved with very little link margin. The discovery range and the working range are assumed to be very similar. In contrast, in what we imagine to be a typical MEP discovery process, we may find that a signal that's loud enough to be demodulated at our data rate is rather easy to detect over a fairly wide range of angles, even with a dish.

Increasing the beamwidth

Increasing the beamwidth is similar in concept to using a spotting scope on a telescope. You have a wider field of view, and less magnification. You orient yourself in the part of the sky you are observing, and then, once you are satisfied that you are pointing at the right object then you switch to the higher-power view through the telescope.

One way to accomplish increasing the beamwidth is by defocusing the dish. Defocusing the dish means moving the feed away from or towards the reflecting surface of the dish. Another way to accomplish increasing the beamwidth is by using a second feed pointing out along the boresight instead of towards the reflector.

The advantage of this method is that a second transceiver isn't required, as is with the method of using APRS discovery on 2m.

While the gain is reduced using these two strategies, it might be possible to match the discovery range to the working range because of the different link requirements of the discovery range compared to the working range.

Action item: present link requirements for working vs. discovery range.

If discovery works on a narrowband feature of the transmitted signal, it might well be able to detect signals even weaker than the system can demodulate and decode. The narrowband feature could be transmitted solely for that purpose, or it might also be useful as a pilot signal or low-rate data subcarrier.

A disadvantage with this kind of discovery is that it can only find stations which are actively transmitting. This can be mitigated with protocol design, but that leads to problems of power consumption and scalability, as well as concerns about unattended operation.

Using APRS query/response and filtering the replies

APRS on 2m

Automatic Packet Reporting System (APRS) provides the functions required for station discovery and pointing.

As Bob Bruninga describes at www.aprs.org, “(APRS) is a two-way tactical real-time digital communications system between all assets in a network sharing information about everything going on in the local area. On ham radio, this means if something is happening now, or there is information that could be valuable to you, then it should show up on your APRS radio in your mobile. APRS also supports global callsign-to-callsign messaging, bulletins, objects email and Voice because every local area is seen by the Internet System (APRS-IS)! APRS should enable local and global amateur radio operator contact at anytime-anywhere and using any device."

An APRS-equipped transceiver with omnidirectional antenna is attached to or integrated with each MEP station. Using APRS discovery, the searching station determines the locations of other stations, find out which directions the other stations are currently pointing, and what services, modes, or missions the other stations have. The information is updated in real time and can be obtained by passively monitoring for station beacons or by actively searching using a query and response method.

The APRS process involves the following steps. First, newly arrived stations make an APRS query or waits for all stations in range to transmit their beacons. Second, the query or beacon is interpreted according to standard APRS protocol. MEP stations must have had a particular status configured in advance. Finally, responses or beacons are filtered by the querying station, based on the content of the status, and results are presented to the operator or automated station equipment.

An advantage to this method is that the information learned about the stations is more detailed than the information that can be learned from scanning for transmitting stations in the microwave band with either a focused or a defocused (wider-angle) beam. Another advantage is that stations need not be actively transmitting on the microwave bands in order to be found by the searching station.

A disadvantage of this method is that it may produce a list of stations that are within VHF range but not within microwave range. This means that the list of stations may include some that are out of microwave range but within VHF range or stations that are within VHF range but not on a line-of-sight path. Work needs to be done to match, as closely as possible, the VHF discovery range to the microwave working range. Finally, station status must be properly configured and additional VHF equipment reliably working if automatic discovery via APRS is to work. This method is also subject to spoofing, since any APRS station can copy the status of a MEP station and masquerade as a MEP station.

From the APRS specification, "Queries always begin with a ?, are one-time transmissions, do not have a message identifier, and should not be acknowledged. Similarly the responses to queries are one-time transmissions that also do not have a message identifier, so that they too are not acknowledged."

Table 1: Query with Target Footprint Format

?	Query Type	?	Lat	,	Long	,	Radius
1 byte	n bytes	1 byte	n bytes	1 byte	n bytes	1 byte	4 bytes

Table 2: Example Query

Query with Target Footprint	Typical Response

?APRS? 34.02,-117.15,0200	/3402.78N11714.02W->Digi on low power

In Table 2 Query with Target Footprint, a general query for stations within a target footprint of radius 200 miles centered on 34.02 degrees north, 117.15 degrees west is shown.

For stations within a particular target footprint, the latitude and longitude parameters are in *floating point* degrees (*not* in APRS lat/long position format). North and east coordinates are positive values, indicated by a leading space. South and west coordinates are negative values. The radius of the footprint is in miles, expressed as a fixed 4-digit number in whole miles. All stations inside the specified coverage circle should respond with a Position Report and a Status Report.

In Table 2 Typical Response, a station response with standard position and status is shown. In the typical response, the data type identifier “/” leading the response indicates a position with timestamp (no APRS messaging).

Position coordinates are a combination of latitude and longitude, separated by a display Symbol Table Identifier, and followed by a Symbol Code.

For example:
4903**.**50N**/**07201.75W-

Latitude is expressed as a fixed 8-character field, in degrees and decimal minutes (to two decimal places), followed by the letter N for north or S for south. Longitude is expressed as a fixed 9-character field, in degrees and decimal minutes (to two decimal places), followed by the letter E for east or W for west.

The **/** character between latitude and longitude is the Symbol Table Identifier (in this case indicating use of the Primary Symbol Table), and the **–** character at the end is the Symbol Code from that table (in this case, indicating a “house” icon).

A description of display symbols is included in Chapter 20: APRS Symbols of the APRS Protocol Reference. The full Symbol Table listing is in Appendix 2.

The specific types of information most important to MEP discovery include the following: boresight azimuth, boresight elevation, station position in latitude longitude altitude. A case for omnidirectional antennas should be reserved. Not all stations will use highly directional dishes.

While position in latitude and longitude is well-established, what parts of the APRS protocol work best for communicating boresight azimuth and elevation? The directivity field in the data extensions is a bit too coarsely grained for the 8-12 degree 3dB beamwidths we're expecting. This leaves either the comment field (e.g. "MEP 10W at 22 degrees") or developing a user-defined data format.

Using omnidirectional in-band beacons and in-band signaling

A third method is to use an omnidirectional in-band beacon or signal. All discoverable stations would transmit an omnidirectional signal at all times, at time intervals as a beacon, or in response to a query. Once other stations are discovered, the directional antenna would be used to communicate.

In the case of continuously transmitted signals, the setting aside of a set of control channels that help stations find each other is a well-known technique in mobile wireless telephony. Many of the practices are applicable to MEP. In the case of an in-band beacon or query/response, APRS could be used as the in-band omnidirectional signaling method. This eliminates the disadvantage of having extra equipment, as would be the case with requiring a 2m APRS transceiver. While MEP stations would not be transmitting on the 2m APRS channel, they could be placed as objects so that 2m APRS stations would be able to discover them.

Can you suggest another clever way to make microwave dish pointing faster and easier? Please join the discussion on our mailing list. Find us on the web at www.delmarnorth.com/microwave

Research Question: For discovery purposes, we have concentrated on line-of-sight paths. However, there are non-line-of-sight paths in microwave operation. Weak signal operators use them effectively. Can these paths be usable for a high-rate data signal? How would one characterize a non-line-of-sight microwave path?