Microwave Engineering Project (MEP) Update
The Problem is Pointing

By Team MEP[i]
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Most microwave stations use dish antennas. Dish antennas at the frequencies of operation of interest to MEP, which range from 3.4GHz to 5.6-5.8GHz, 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 direction finding packet format
- 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 any antenna, the process of increasing the beamwidth 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. Work is ongoing to define and model these ranges.

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.

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.

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 that 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 direction finding packet format

As Bob Bruninga describes at www.aprs.org, "Automatic Packet Reporting System (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."

Enabling contact is the purpose of the discovery function. The APRS Direction Finding (DF) packet format provides a useful framework for communicating the station discovery information, which includes the position of the station, the direction the station antenna is pointing, the beamwidth of the station, the frequency of the station, and the course and heading if the station is mobile. The information is updated in real time and can be obtained by passively monitoring for station beacons.

In order to accomplish station discovery with APRS, an APRS-equipped transceiver with omnidirectional antenna is attached to or integrated with each MEP station. APRS provides the functions required for station discovery and the results could be input to an automatic pointing subsystem. Because an existing packet format is used, the implementation requires less work than if a custom packet format was developed. The services, modes, or missions of other stations can be determined by APRS query and response, after the station is discovered.

How MEP will use the APRS DF Packet Format

Position coordinates in APRS 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 precision of two decimal minutes of longitude or latitude is about 25 meters.

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).[ii]

The DF bearing format gives 1-degree pointing precision and also allows for a beamwidth field. Referred to in the specification as Quality (the Q in the NRQ field, explained below), it can express station beamwidth so that other stations could plot an estimate of the antenna pattern. A case for omnidirectional antennas should be reserved. Not all stations will use highly directional dishes.

From page 30 of the APRS Specification[iii],

> DF reports contain an 8-byte field /BRG/NRQ that follows the CSE/SPD Data Extension, specifying the course, speed, bearing and NRQ (Number/Range/Quality) value of the report. NRQ indicates the Number of hits, the approximate Range and the Quality of the report.
>
> For example, in:
>
> …CSE/SPD/BRG/NRQ…
> …088/036/270/729…
>
> course = 88 degrees, speed = 36 knots, bearing = 270 degrees, N = 7, R = 2, Q = 9
>
> BRG is 001 to 360, with 000 indicating an omni-directional antenna.
>
> The N value is not processed, but is just another indicator from the automatic DF units.
>
> The range limits the length of the line to the original map's scale of the sending station. The range is 2^R so, for R=4, the range will be 16 miles.
>
> Q is a single digit in the range 0–9, and provides an indication of bearing accuracy. MEP will use bearing accuracy for beamwidth.

Table 1: Bearing Accuracy

Q	0	1	2	3	4	5	6	7	8	9
Accuracy	Useless	<240°	<120°	<64°	<32°	<16°	<8°	<4°	<2°	<1°

From the APRS Specification page 34,

> DF Reports are contained in the Information field of an APRS AX.25 frame. The BRG/NRQ parameters are only meaningful when the report contains the DF symbol (i.e. the Symbol Table ID is / and the Symbol Code is \). If the DF station is fixed, the Course value is zero. If the station is moving, the Course value is non-zero.

Table 2: DF Report Format – without Timestamp

Field	! or =	Latitude	Symbol Table ID /	Longitude	Symbol Code \	Course/Speed Power/Height/Gain/Dir Radio Range DF Signal Strength	/BRG/NRQ	Comment
Number of bytes	1	8	1	9	1	7	8	0-28

The next element of information is frequency of operation. This is anticipated to be useful in case MEP employs frequency agility over a large enough portion of the amateur band to where bandwidths can't be assumed to overlap, or to show which band the station is operating on. MEP stations operate in either point-to-point or multiple access modes. Point-to-point operations may occur on a single band. Multiple-access is a dual-band mode. Being able to communicate a frequency may be useful for MEP.

The frequency field, which is part of the proposed APRS Specification 1.2, is expressed as FFF.FFF in MHz. Since MEP stations operate at 3GHz and above, a minor change is needed to express microwave frequencies.

A letter is used to stand for the two numbers that express the thousands and hundreds of MHz. Here are four examples. D stands for 34, E stands for 56, F stands for 57, and G stands for 58.

Table 3: How Codes Enable Microwave Frequency Expressing in Frequency Field

Field	D01.000	E51.000	F60.000	G30.000
Frequency in MHz	3401	5651	5760	5830

Transmitting with one hop via WIDE1-1 once a minute while active has been recommended[iv]. If the station is more than one hop away, the odds of a microwave path are thought to be low. Keeping APRS traffic to one hop also helps to keep the man-made interference low.

Here is a template DF packet format with all the fields mentioned so far.

AX.25 HEADER: CALLSIGN>APMEPv,WIDE1-1
DATA: =DDMM.mmN/DDDMM.mmW\000/000/BRG/NRQ/FFF.FFFMHz ATV-MEP

An advantage to using APRS for station discovery 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.

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 as described in the previous section. 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 station discovery and microwave dish pointing faster and easier? Please join the discussion on our mailing list. Find us on the web at www.delmarnorth.com/microwave

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[i] People contributing to this document include Bob Bruninga, Michelle Thompson, Paul Williamson, Timothy Salo, Roger Thompson, and Ken Easton.

[ii] 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.

[iii] the full title, attribution, and URL of the APRS spec

[iv] Recommended to MEP by Bob Bruninga via email in November 2008.