Paper Session FR-A1.3A.2

30-2000 MHZ MULTI-BAND BODY WEARABLE ANTENNA (MBWA)

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2017 IEEE International Antenna & Prop. Symposium and URSI Radio Science Meeting
San Diego, CA, USA
July 9-15, 2017

US Army's vision of Multi-Band Wearable Antenna (MBWA)

- Compatible with Army radios RT-1523, PRC-148, and PRC-152
  - single input/output to radio,
  - operating one band at one time.
- Minimum range of 0.5 KM when both transmitter and receiver are in horizontal positions on the ground.
- Can be remoted from radio and soldier to enhance communications range in heavily forested or triple canopy jungle environments.
- Low cost, low weight, small volume, and rugged.
- Meeting microwave radiation hazard safety requirements.

Specifications for:
Harris Falcon III® AN/PRC-152A Wideband

GENERAL	
RT Nomenclature	RT-1916x(P)(C)/U
Frequency Range	30 - 870 MHz Narrowband: VHF 30-225 MHz, UHF 225-512 MHz Legacy SATCOM: RX 243-270 MHz, TX 291-318 MHz High Band (VULOS/P25): 512-520 & 762-870 MHz Wideband: 225-450 MHz
Channel Spacing/Bandwidth	Narrowband: 8.33,12.5, 25 kHz-AM, 12.5, 25 kHz-FM SATCOM: 5 kHz, 25 kHz Wideband: 500 kHz, 1.2 MHz FM Deviation: 5 kHz, 6.5 kHz, 8 kHz

Thales' PRC-148 covers 30-512 MHz

AN/PRC-148 JEM

JTRS Enhanced Multiband Inter/Intra Team Radio

THALES

- Contiguous 30-512 MHz Coverage
- 256 Programmable Presets
- Smallest and Lightest Multiband Handheld Available
- Programmable Encryption Engine (AIM)
- Waveforms/Modes (Implemented and Planned)
  - AM/FM
  - HAVEQUICK I/II
  - MIL-STD-188-241-1/-2 (SINCGARS)
  - MIL-STD-188-181B (56 kbps)
  - MIL-STD-188-181C, -182B, -183B (SATCOM IW)
  - ANDVT
  - Project 25
  - Over The Air Cloning (OTAC)
  - Retransmission
- Part of a Complete Communications System for Mounted and Dismounted Operation (See page 3 for details)

Additional Functionality for the AN/PRC-148 JEM with Simple Software Downloads

TECHNICAL SPECIFICATIONS

Frequency Range
- 30-512 MHz Contiguous
- 5 kHz and 6.25 kHz Step Size

Frequency Stability
- 1 ppm

Audio Capabilities
- Internal speaker/microphone
- > 85 dBSPL acoustic output power

Transmit Output Power
- User selectable
- 0.1, 0.5, 1.0, 3.0 and 5.0 Watts (waveform dependent)

Transmit Characteristics
- Radiated spurious output: < -13 dBm
- Audio distortion: < 10%
- Adjacent channel power ratio: > 45 dBc

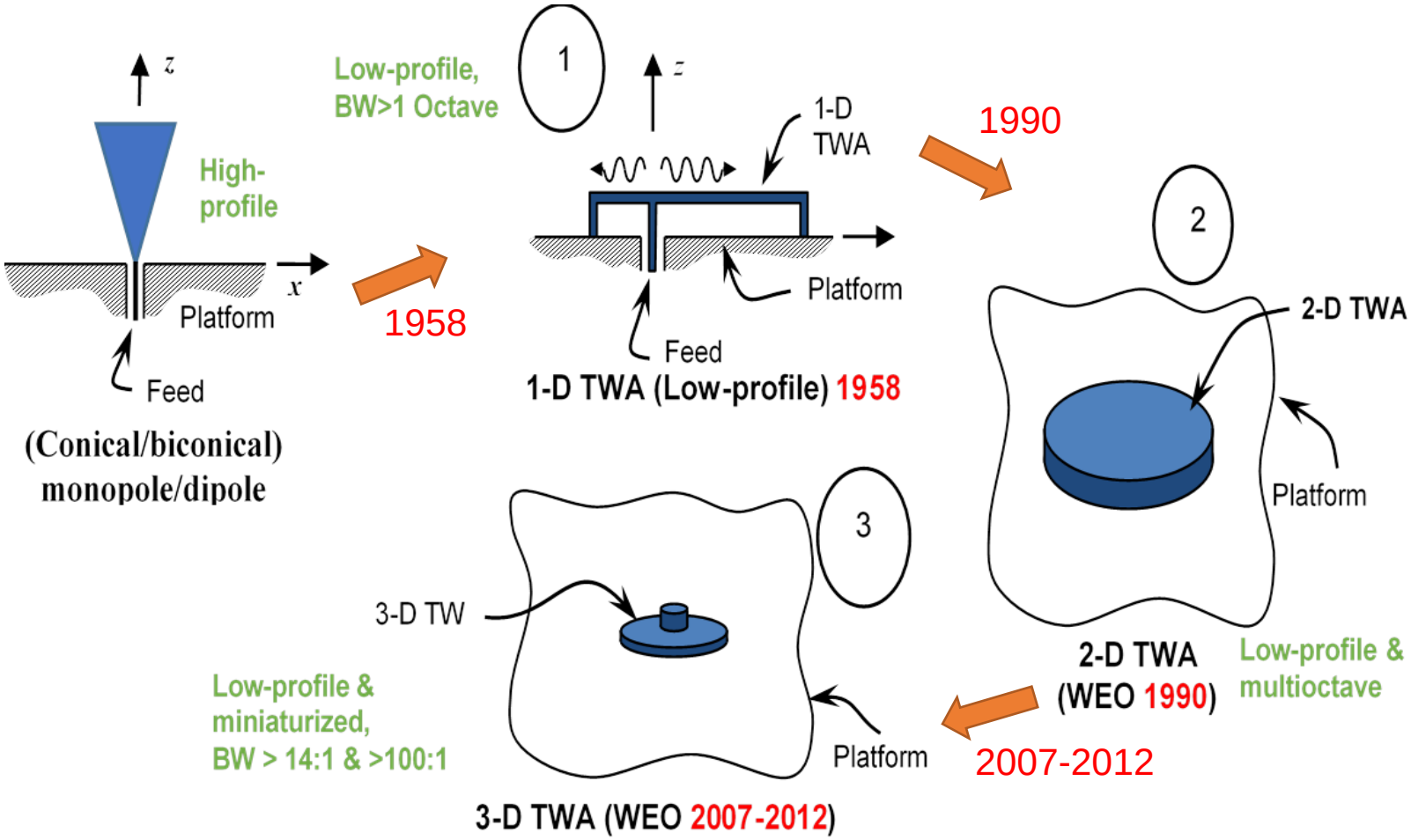
Frequency coverage: six-bands 30-2000 MHz

System served	Freq. (MHz)	Pol	Gain	Pattern	Sat/Ter	Tx/Rx
SINCGARS band	30-88	LP	TBD	Omnidiretional	Terrestrial	**Tx/Rx**
Air & Marine band	116-174	LP		Omnidiretional	Terrestrial	**Tx/Rx**
UHF Comm.	225-450	LP	TBD	Omnidiretional	Terrestrial	**Tx/Rx**
UHF-Public Safety	450-512	LP	TBD	Omnidiretional	Terrestrial	**Tx/Rx**
UHF SATCOM	225-318	**RHCP**	TBD	Hemispherical	Satellite	**Tx/Rx**
L-Band (Soldier Radio Waveform)	1000-2000	LP	TBD	Omnidiretional	Terrestrial	**Tx/Rx**

Technical difficulties are extremely high!

- Wideband/multiband requirements under constraints of size, weight, and shape covering 2 GHz down to 30 MHz (67:1 operating bandwidth).
- The irreducible size of antennas is one of the three fundamental technological barriers for future wireless.
  - The well-known Chu Limit (J Appl Phys 1948)
- UHF Satcom requires different pattern (hemispherical) and polarization (RHCP).
- Weight limit as a wearable.
- Low cost as a soldier-level gear.

WEO's patented 2-D and 3-D omnidirectional Traveling-Wave Antennas (TWA) are employed to overcome the difficulties



How TWA circumvented the Chu Limit*

- TWA is low-profile. TWA hides its size—behind its ground plane.
  - conveniently integrated into the platform or the earth ground —on which the antenna is mounted.
- The theory of Chu Limit is only applicable to antennas with a high Quality Factor (Q) of, say, 5 or higher
  - TWA is a low-Q antenna, thus can achieve bandwidth enormously wider than the Chu Limit.

***J. J. H. Wang, "A Critique and New Concept on Gain Bandwidth Limitation of Omnidirectional Antennas," PIERS 2005, Hangzhou, China, August 2005.**
***J. J. H. Wang., "Fundamental Bandwidth Limitation for Small Antennas on a Platform," 2006 IEEE IWAT, White Plains, New York, March 2006.**

Top-level design concept of MBWA

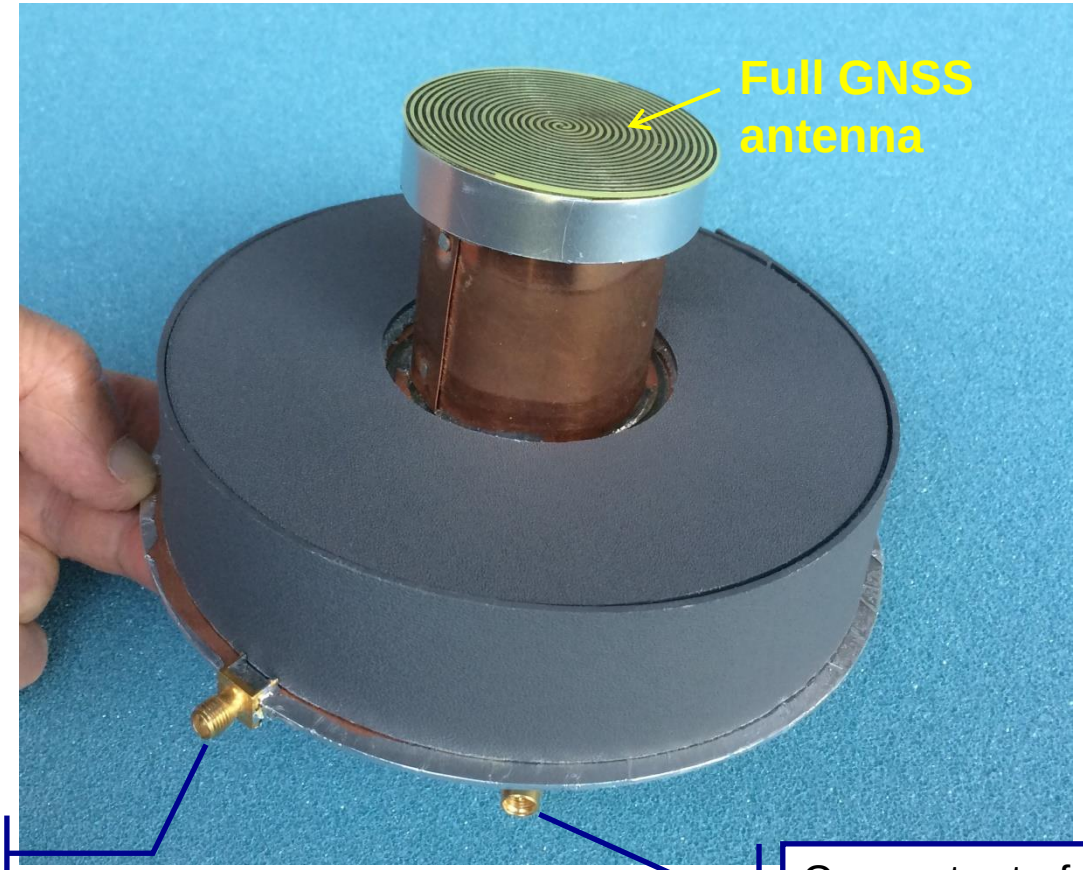
- Has two input/output connectors, one for LP (Linear Polarization) MBWA and the other for RHCP (Right Hand Circular Polarization) UHF SATCOM.
- Has two states:
  - (1) Operating,
  - (2) Carrying and stowing (in two camouflage bags, one for LP MBWA ensemble and the other for RHCP MBWA).
- Has two modes of operation
  - On ground
  - Remoted from radio and soldier in heavy forest, triple canopy jungle, special terrain/structure, etc.

Breadboard LP MBWA ensemble in carry/stow mode beside an Army multiband radio AN/PRC-152

- Shown in carry/stow-mode inside camouflage bag
- 30-2000 MHz bandwidth
- LP omnidirectional coverage
- Weight ~1.5 Kg

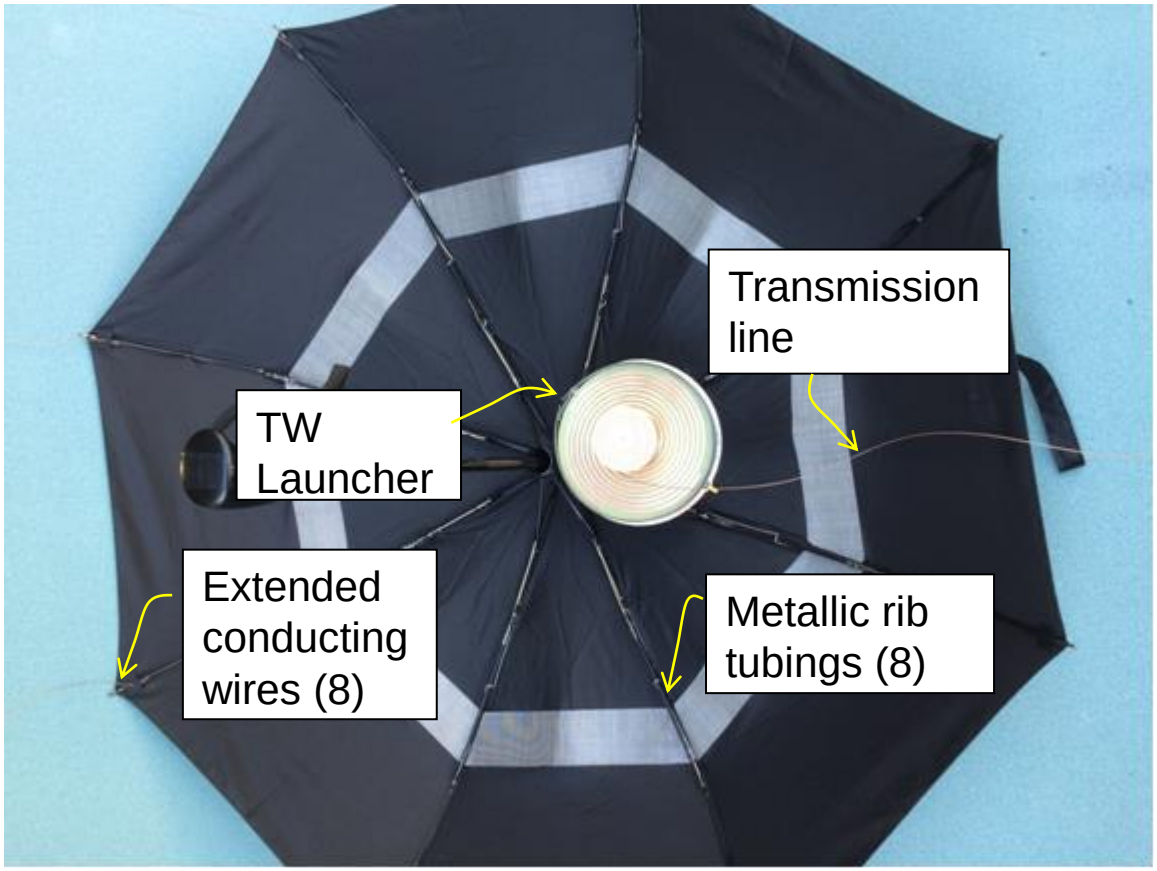
Heart of MBWA— TWA (Traveling-Wave Antenna)-launcher

TWA Launcher alone can cover 500-2000 MHz for LP Comm and full GNSS!



LP MBWA ensemble with umbrella telescoping activated for operation on ground for full 30-2000 MHz

Eight (8) extended conducting wires serve to create a “ground plane” (GP) 10 meters in diameter.



RHCP MBWA Breadboard for UHF SATCOM

- Mode-1 2-D TWA.
- Carried in a separate camouflage bag.
- **Weighs only 0.5 Kg (**0.7 Kg if bag included).
- Currently 11.5 cm thick and 64 cm in diameter. It will be modified to a foldable configuration of about the same weight but can be contained in a bag about 64cm×30cm×15cm in size.

Test Methodology from 100 to 6000 MHz

Antenna		System	
Parameters		Analog	Digital
VSWR (Impedance matching)	Necessary	Necessary	Necessary
Gain pattern	Sufficient	Sufficient	Gain requirements greatly relaxed via MIMO*

*** MIMO = Multiple-In Multiple-Out (for the channel)**

Measured VSWR and gain over 100-2000 MHz are satisfactory

- Conventional antenna tests were conducted in WEO's anechoic chamber.
- Tests were carried out with the MBWA as a transmit antenna. (Based on the principle of reciprocity)
- Measured SWR and gain patterns for MBWA are fairly good for the three high bands. Though marginal for Air & Marine band, the performance should be good as the channels are in ***MIMO*** environments.

Tests at 30-88 MHz SINCGARS band

- Below about 100 MHz, low SWR is necessary but not sufficient. The power may be dissipated by the ground, not radiated. And the channels are not amenable to MIMO. Thus “field tests” are desirable or even necessary.
- A Vector Network Analyzer is used as the transmitter feeding the MBWA, the signal strength at a far-field location in a distant separate room in the same building is measured on Spectrum Analyzer using a standard-gain dipole antenna.
- The relative performance of MBWA is obtained by calibrating it against a 1.24-m Thales Whip Blade Antenna.

Relative signal strength measurement for WBWA shows good performance over Thales whip antenna

Measured Relative Signal Strength

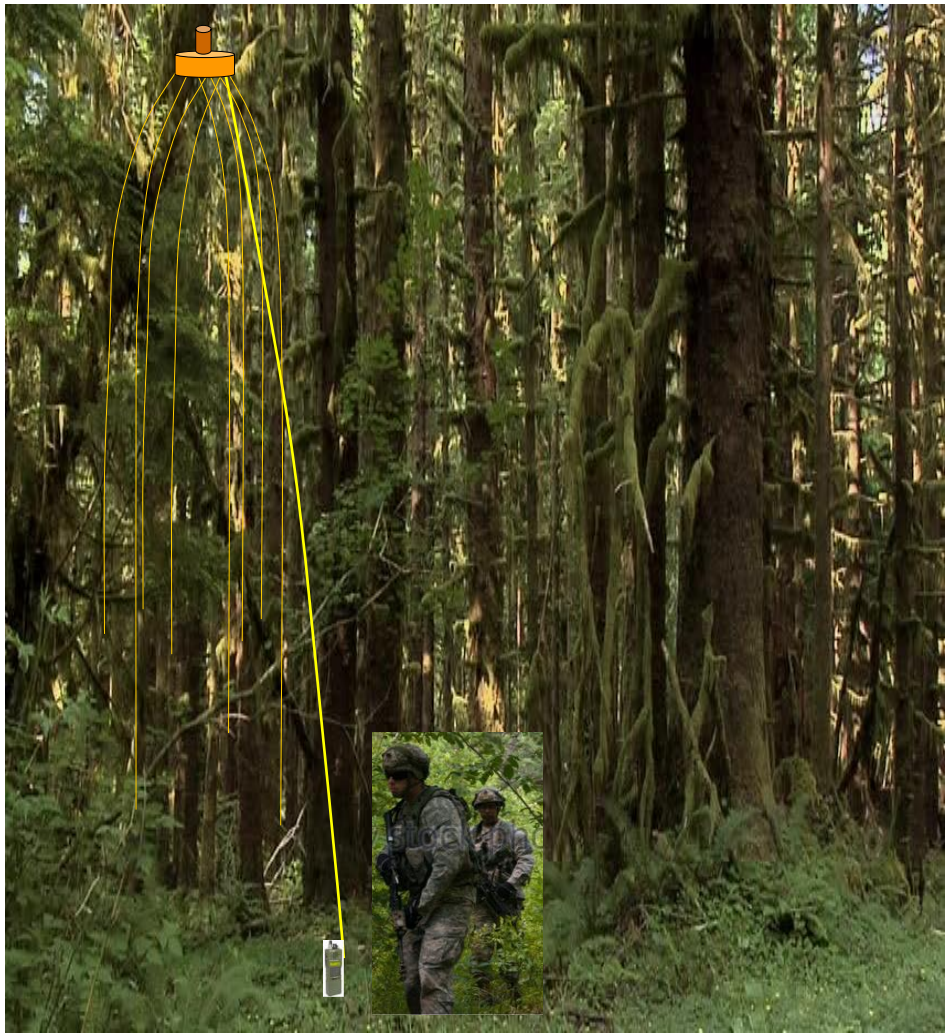
WEO MBWA VS. Thales 1.24 Meter Whip Antenna

	P_{WEO} (WEO MBWA)		P_{Thales} (Thales 1.24 Meter Whip)		P_{WEO}/P_{Thales} (WBWA/Thales)	
40 MHz	-45	dB	VP	-42 dB	-3	dB
			HP	-48 dB	3	dB
	HP only		45˚ angle	-56 dB	11	dB
50 MHz	-51	dB	VP	-52 dB	1	dB
			HP	-52 dB	1	dB
	HP only		45˚ angle	-55 dB	4	dB
60 MHz	-48	dB	VP	-50 dB	2	dB
			HP	-52 dB	4	dB
	HP only		45˚ angle	-62 dB	14	dB
70 MHz	-51	dB	VP	-50 dB	-1	dB
			HP	-47 dB	-4	dB
	HP only		45˚ angle	-48 dB	-3	dB
80 MHz	-62	dB	VP	-66 dB	4	dB
			HP	-63 dB	1	dB
	HP only		45˚ angle	-68 dB	6	dB
90 MHz	-82	dB	VP	-80 dB	-2	dB
			HP	-76 dB	-6	dB
	HP only		45˚ angle	-75 dB	-7	dB

- Note that for the 30-90 MHz tests, the Thales whip antenna as the calibration antenna was never laid horizontally on the ground.
- If the Thales whip antenna had been laid horizontally on the ground, it could lose most of its antenna capability!

Hoist MBWA high in heavy forest or triple canopy jungle to increase communications range

- MBWA raised up into a tree using a small roped gear.
- Radio and soldier stay on ground.
- Effective signal strength is raised; thus RF comm range increased.
- The test was part of the tests planned at Army CERDEC.



Estimate on SAR (Specific Absorption Rate) for MBWA

- SAR is dependent on the transmitted power from the radio.
- Both LP MBWA and RHCP UHF SATCOM MBWA are safer than other wearable antennas (i.e., having lower SAR) since
  - The TW radiation is nonresonant.
  - The waveforms of these military radios have wideband frequency-hopping and spread-spectrum features. Thus they are much less likely to generate “hot spots” than cellphones, which operate on fixed narrowband channels.

Advantages over legacy antennas

	WEO LP-MBWA	*AT-271A/PRC 8-foot metal foldable stick*	*AS-3683/PRC 1-meter Whip*
Low profile	Yes	No	No
Weight	1.5 Kg	0.3 Kg	0.26 Kg
Cover all 5 LP bands	Yes, all 5 bands	No, 1 band only (SINCGAR)	No, 1 band only (SINCGAR)
Broadband	Yes, for all 5 LP bands	No. Covering 25-123 MHz by 7-section tuning	Yes, but only for SINCGAR 30-88 MHz
Remoting to tree tops	Yes	No.	No
Antenna on ground	Small loss only below 500 MHz	High loss	High loss
Cost per unit	Can be cost-competitive	$80	$60

Potential advantages in 5G Wireless for frequencies below 6GHz

	WEO MBWA-TWA	RIM-Blackberry	Other cellphones
Security/privacy	Excellent	Weak and limited	Very vulnerable
Physical-layer security	Yes	None	None
Cell throughput	>100 Gbps	10 Gbps	10 Gbps
Air latency	<0.01 msec	<1 msec	<1 msec

Concluding Remarks

- A breadboard model for MBWA has been developed and tested successfully at WEO and at US Army CERDEC, thus advancing both TRL (Technology Readiness Level) and MRL (Manufacturing Readiness Level) to level 4.
- The MBWA covers six communications bands quite well, ranging from 30 MHz to 2 GHz.
- Mass production of MBWA (and the Army radios) has the potential of application in 5G Mobile Wireless for frequencies below 6 GHz in dealing with both capacity and security issues.*

  *J. J. H. Wang, “Wideband Wide-Scan Millimeter-Wave Phased Arrays for Enhanced Security/Privacy and Performance in 5G Mobile Wireless,” Paper # Special Session TH-SP.1P.8, this Symposium.

Acknowledgment

This research was supported by US Army CERDEC under Contract No. W56KGU-16-C-0073 and WEO IR&D in a six-month effort.

Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the US Army.